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Climate change and higher education: Assessing factors that affect curriculum requirements

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ABSTRACT

Pervasive misinformation about climate change might be reduced if colleges were to include the topic within general education curriculum. This paper analyzes the general education (or "core") curriculum in the top 100 universities and liberal-arts colleges in the U.S. to assess the proportion of core courses that highlight climate change or climate science. The probability that a student takes at least one climate-change course via the core curriculum is estimated at 0.17 across all schools. The probability is higher at research universities than at liberal arts colleges, in core programs that have more science and social science courses, and at public universities in states with a Democrat-controlled legislature than in states with a Republican-controlled or split legislature. Drawing on cases of best practices in the U.S. identified from the data set, the authors discuss strategies that could ensure a higher likelihood that the core curriculum includes education on climate science and climate change. The study advances the broader research literature on sustainability in higher education programs by bringing it into conversation with research on the college core curriculum and by focusing both on the specific issue of climate-change education.

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1. Introduction

Although there is a scientific consensus that climate change is occurring, public opinion polls indicate that in many parts of the world there is lack of awareness of the issue (Lee et al., 2015) and that the level of concern about climate change varies widely from one country to another (Carle, 2015). Furthermore, the level of commitment among countries has varied significantly, from the different responses to the Kyoto Protocol during the 1990s to the decision by President Trump to withdraw the U.S. from the Paris Climate Agreement. Various international statements and declarations have emphasized the importance of improving higher education for sustainability as one approach to improving awareness among the public and political leaders about the issue (Lozano et al., 2013). Many colleges and universities have also recognized student, government, and employer interest in the area by investing in new curricula, even though the investments have often faced institutional and financial barriers that have slowed progress (Vincent et al., 2015).

The role of universities and colleges is especially important in areas of the world where some opinion leaders and media outlets have created confusion among the public about environmental issues such as climate change. For example, in the U.S. conservative foundations and donors associated with the fossil-fuel industry have financed an organized movement to deny the scientific consensus on climate change (Dunlap and McCright, 2015). Lobbying, campaign funding, and disinformation in the U.S. have accentuated partisan divisions about the reality of climate change and the need for mitigation policy. Furthermore, similar divisions can be found in Canada, Australia, the U.K., and other countries (McCright and Dunlap, 2011; McCright et al., 2016).

In this situation, higher education institutions can provide one important source of countervailing institutional power to misinformation and lack of political support for policy mitigation. Educational attainment is the strongest predictor of climate-change awareness (Lee et al., 2015), and a teacher's belief that global warming is happening appears to predict a student's belief (Stevenson et al., 2016). However, educational attainment interacts with political beliefs (Hamilton, 2011; McCright and Dunlap, 2011). For example, a college education in the U.S. is associated with an increase in belief about global warming for liberals (a term meaning politically "left" of center) and for members of the left-of-center

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Democratic Party. Specifically, for those without a college education, only 61% of liberals and 60% of Democrats believe in global warming, but the percentage increases to 82% of liberals and 79% of Democrats who have a college degree (McCright and Dunlap, 2011). However, differences are negligible for conservatives with and without a college degree and minor for Republicans (ibid.).

A pessimistic interpretation of this finding is that a college education will have little impact on belief in climate change or global warming among students who already have a belief lock-in because of political commitments. However, it is also possible that students who doubt the consensus on climate science will tend to self-select out of courses related to the topic, that is, to show confirmation bias for their existing views (Nickerson, 1998). For example, more conservative students may drop a class when they find out that there is going to be substantial coverage of climate change and/or climate science. This problem could be addressed by requiring that climate-related education be a part of the college education, and the most likely vehicle for doing so would be a modification in the college core curriculum. Thus, this study contributes to efforts to improve higher education on environmental issues in general and climate change in particular by examining the extent to which students are likely to receive climate-change education as part of the core curriculum, the factors that affect some of the variation in the inclusion of climate change in the core curriculum, and strategies for gaining greater inclusion of climate-change education in the college core curriculum.

The argument is developed in two parts. The first part is a review of the literature on the general education curriculum and on attempts to reform the curriculum to include environmental and sustainability (ES) issues. Because the goal of embedding knowledge about climate science and climate change in the college curriculum is part of broader efforts to bring sustainability into the college curriculum, this general literature is relevant. The study's contribution within this substantial literature is to connect research on the general-education curriculum with research on environmentally related curriculum reform in the college curriculum and to focus both on the issue of climate-change education. The second part presents the results of an analysis of climate change and the core curriculum in 100 leading colleges and universities in the United States, and it also examines some strategies for improving the likelihood that college students will receive education on climate change and climate science.

1.1. The general education curriculum and sustainability

There is a literature on general education (also designated here as “core curriculum”) in higher education and a literature on the sustainability curriculum in higher education, but these two literatures have to date been mostly separated. This section will review both and then suggest some research questions with respect to the issue of embedding climate change education in the college general education requirements.

General education requirements are cast against the background ideal of a liberal arts education that seeks to provide students with a basic knowledge of the natural sciences, social sciences, and humanities (Stevens, 2001). The general education requirement also ensures that students have the skills necessary to learn at a rigorous level, and it allows students to gain perspectives on a breadth of topics, including contemporary issues, as part of a broad education that can also provide the basis for future study in a graduate professional program (Association of American Colleges and Universities, 2015). Although these traditional rationales for the core curriculum continue to be used today, efforts to change or modify it also take place within a changing political economy, where universities are positioned as engines of economic innovation and where students seek degrees that include some practical skills to enhance their prospects in a competitive global economy (Bessant et al., 2015). These historical changes situate the topic of environmental education and the core curriculum in cross-currents that both improve and restrict opportunities. In other words, education in science, technology, and global issues is valued, and global environmental science and policy can be included in this mix, but some forms of humanistic and critical inquiry may suffer a corresponding devaluation (Cantwell and Kauppinen, 2014).

With respect to the specific literature on the core curriculum, there are different strategies for structuring the core, and there is longstanding debate over how much the core should include shared courses versus menus and choices (Boyer and Kaplan, 1994; Stevens, 2001; Zai III, 2015). The “list of courses” approach ensures some uniformity and potentially better coordination between curricular goals and classroom instruction. Student evaluations also tend to be more favorable when the course is required (Tuazon, 2015). However, the “list of courses” approach is rigid, difficult for transfer students, and out of tune with the broader ideological and economic currents that emphasize flexibility and innovation (Cantwell and Kauppinen, 2014). There are also practical difficulties such as recruiting faculty to general courses at an introductory level, especially if the courses are interdisciplinary and involve team-teaching (Zai III, 2015). In contrast, distribution requirements allow students to have a more individualized educational experience, and departments can all gain by having their courses listed as part of the core (Hachtmann, 2012). The strengths and weaknesses of each approach have been debated, but there is a current trend toward distribution requirements in the most prestigious higher-education institutions (Bourke et al., 2009).

Another major difference in general education programs involves those of liberal arts colleges and research universities. In the U.S., a liberal arts college is a four-year college that generally offers students a broad undergraduate education during the first four years after high school. The education leads to a bachelor's degree in the humanities, social sciences, and sciences, and historically it does not focus on technical or professional education (Shulman, 2001). Often these colleges are privately owned and may have a religious affiliation, but some are part of public university systems. Some students prepare to pursue graduate education in law, business, medicine, or another profession, and some go directly into the workforce upon graduation. In contrast, a research university offers the full range of undergraduate education, including liberal arts and technical programs, as well as both graduate degrees in Ph.D. programs and in professional schools (Shulman, 2001). On average, liberal arts institutions have a higher number of required core courses (an average of 12) than do research universities (Bourke et al., 2009). Liberal arts colleges have also pioneered a new model of general education, the open curriculum, which enables students to work with their advisors to determine an individualized plan that ensures breadth and depth across the curriculum (Bourke et al., 2009; Elphick and Weitzer, 2000).

Research on general education has also characterized the factors that affect why the core curriculum changes in both liberal arts colleges and research universities. Often major changes are driven by the administration rather than by faculty, and these changes can in turn reflect goals set by accreditation agencies (Zai III, 2015). However, incremental changes occur when faculty add and delete courses each year and when faculty form coalitions in favor of change. Both types of changes are only partly based on an assessment of curricular needs, and they may also emerge from changes in funding and personnel (Hachtmann, 2012). External factors include changes in the requirements for graduate schools and changes in the skill set required for jobs and careers, both of which are conditioned by the broader historical transformations

described above (Brint et al., 2009). For example, businesses sometimes require specific qualifications from college graduates in order to hire them, and colleges and universities work to meet the job market's expectations in order to provide improved job placement (Hachtmann, 2012).

Although proposed general education changes can include adding environmental and sustainability (ES) course requirements, it is not a salient topic in the general education literature. Likewise, the second literature considered here, on ES curriculum development, generally does not involve the analysis of the core curriculum. The literature on the ES curriculum is quite substantial and includes diverse topics such as possible ES implementation strategies (Lozano et al., 2013; Sibbel, 2009), the impacts of ES education (Cortese, 2003; Desha et al., 2009; Moody and Hartel, 2007; Sibbel, 2009), the analysis of implemented ES courses and programs (Fisher and McAdams, 2015; Hegarty et al., 2011; Moody and Hartel, 2007), and methods and indicators for measuring sustainability and the curriculum and the effects of sustainability education on student beliefs (Ceulemans et al., 2015; Shephard et al., 2015). Of this body of research, the research that is most directly relevant to this study is on the ways in which institutionalization can occur and on the barriers that prevent the implementation of ES curriculum.

Several studies have focused on the problem of institutionalizing the ES curriculum (Ceulemans et al., 2011; Fisher and McAdams, 2015; Rowe, 2002). Institutionalization can occur through the adoption of new courses that fit into existing programs; the creation of tracks within existing majors; or the development of new majors and minors, such as an environmental studies major. Another approach is to integrate ES goals into pre-existing courses across different departments in a pattern similar to the "writing across the curriculum" model. Yet none of these approaches is helpful if students cannot or do not take the courses. Drawing on student survey data from a public university in the southeastern United States, Fisher and McAdams (2015) found that of the survey respondents, 45% had never taken a course related to sustainability, a statistic that shows the general lack of integration of ES courses and topics into the curriculum. They also suggested that there is not a significant difference in sustainability perceptions of students who take multiple ES courses rather than just one. In other words, even one ES course may be sufficient for improving knowledge about the environment and sustainability. They also found that an integrative course devoted to sustainability positively impacted students' understanding of ES issues, and they argued for the integration of sustainability education in a more multi-disciplinary or inter-disciplinary fashion. However, these results should be interpreted with caution because of the possibility of self-selection of ES courses by students who already are favorably disposed to the topic.

Another approach to the institutionalization of ES curriculum involves attempts to quantify its integration across multiple organizations. These studies show that although ES courses are available as an option for students, generally they are not required for graduation or for general education requirements (Ceulemans et al., 2011; McIntosh et al., 2008; Wolfe, 2001). In a voluntary survey sent to Chief Academic Officers at United States colleges and universities, only 55% of the 496 respondents reported at least one ES course available in the core curriculum, and 39% offered an environmental program with an ES course appropriate for non-environmental majors (Wolfe, 2001). Environmental literacy was a graduation requirement at 12% of the schools, but this result should be interpreted with caution because there may have been response bias (only 42% of the schools responded), and environmental literacy was defined broadly to include the health-environment interface.

A 2008 survey with over 1000 responding colleges and universities in the U.S. provided similar results (McIntosh et al., 2008). Whereas 70% of the institutions reported that at least some of their undergraduates had taken an ES course, only 16% estimated that a majority of undergraduates would take an ES course. Additionally, the survey found that ES courses were only required at 4% of colleges and universities in 2008, compared to 8% in 2001. Furthermore, the lack of ES integration into the higher-education curriculum is not restricted to the U.S. In a study of Flemish applied economics programs, course overviews were used to determine if a course was solely devoted to ES concepts, integrated ES concepts, or did not discuss ES concepts at all (Ceulemans et al., 2011). Only 31% of programs offered courses with ES concepts, and only 11% of academic programs and 29% of professional programs required such courses.

Another group of studies has investigated the differences in ES adoption within colleges and universities. Lozano (2010) and Watson et al. (2013) used the Sustainability Tool for Assessing Universities' Curricula Holistically (STAUNCH©) to analyze different aspects of the education in "sustainable development." Lozano (2010) showed that at Cardiff University, there is substantial variation across schools (academic departments), ranging from over 80% to under 3% of courses offered that relate to environmental education. The study further separated each school's courses into three main areas—economic, environmental, and social—and a fourth area of cross-cutting themes. Schools tended to be innovators in one concept but conservative in another. Watson et al. (2013) also used STAUNCH©, in combination with student surveys, to show variation in the type of ES concepts to which students are exposed in the Civil and Environmental Engineering Curriculum at Georgia Institute of Technology. Although the curriculum requires courses with ES concepts, technical environmental concepts were highly integrated into the curriculum while the other concepts, especially economic and social, were not. These studies suggest that even when students choose to pursue education in a particular discipline fundamentally tied to ES concepts, they may not gain a holistic understanding of sustainable development or ES concepts.

Another group of studies seeks to understand the general lack of ES institutionalization. Desha et al. (2009) explain that integrating an idea into an existing curriculum is a slow process, causing academic institutions to lag behind industry in their institutionalization of ideas. Other studies delineate the causes of the slow transition. Verhulst and Lambrechts (2015) identify 22 factors in three main groups: lack of awareness, the structure of higher education, and lack of resources. In a case study, they identified several barriers to program development both in the university generally and in the curriculum, and the changing winds of financial support were an important factor that affected outcomes. The most commonly cited barriers to institutionalization of ES curriculum include the lack of financial support, lack of priority for the subject matter, and a shortage of qualified faculty to teach ES courses (Ceulemans et al., 2011; Dawe et al., 2005; Thomas, 2004). In some cases, directors of environmental programs face the uphill battle of gaining administrative support to hire interdisciplinary researchers, and often the tenure lines are located in traditional disciplinary departments, where evaluation for promotion and tenure does not reward interdisciplinary research and publication (Vincent et al., 2015). Gaining a higher degree of institutional autonomy than program status, such as departmental or school status, for environmental studies is a crucial condition for gaining the capacity to develop new courses and curriculum (ibid.).

In summary, the existing literature on the core curriculum and on the sustainability curriculum points to several obstacles to the goal of incorporating a climate-change requirement in the general education requirements. With respect to the core curriculum in

general, major changes tend to be in response to external requirements, such as needs for graduate schools or employment, and the changes tend to occur slowly. With respect to the college-level sustainability education, factors that affect the development of ES courses and curriculum include lack of priority and financial support and lack of qualified faculty. Only a small number of colleges and universities require a course on ES issues, and requirements can vary significantly across schools and programs within a university. However, if required, even one course can have an effect on student perceptions, although the effects vary by the type of ES course that is offered or required.

To better understand the role of the core curriculum in enabling students to have access to accurate information about climate change, the first research question is as follows: 1. What is the probability that students will take a course on climate change as part of their college core curriculum? To chart out some possible institutional factors that affect the level of exposure that students have to climate change, the second research question is: 2. What differences are there across types of colleges (e.g., public versus private, research universities versus colleges, and public universities in more liberal and more conservative states)? Finally, a qualitative analysis of best practices is provided to develop some recommendations in response to the following question: 3. What models are there for best practices for further strengthening climate education in the general education curriculum?

2. Method

The data set is drawn from the general education curriculum requirements in a sample of 100 U.S. universities and colleges. The top 50 national liberal arts colleges and top 50 national universities were used based on the ranking in 2016 by *U.S. News and World Report*. Colleges and universities were also classified into public or private, and the curriculum was coded into two different general education models. The first model, a set of mandated courses, was only present in two institutions. Nearly all institutions followed the second model, where multiple courses are offered in a menu of selection. Students select one or more courses from each category to fulfill the general education requirements, often referred to as distribution requirements. Some institutions blend these two models by requiring a set of courses in addition to allowing selection from a menu for some subject areas. Such curricula were classified as part of the distribution requirement model because they allow for student choice in the curriculum.

For each college and university, Collins gathered information on the general education requirements for the main liberal arts college, such as the college of arts and sciences, from the 2015–2016 academic year information. This involved reading the college core requirements, then categorizing the requirements into broad disciplinary areas. Based on an iterative process that began with a broad list of about 20 categories, the categories were consolidated into 11 main groups: natural science, first-year seminar, social science, U.S. history, ethics/philosophy, humanities, international, writing, quantitative, diversity, and other. The category of natural science may include mathematics courses as part of the core area, whereas the category of quantitative is a mathematics-only requirement (such as calculus, statistics, or quantitative reasoning). Ten colleges and universities were excluded from the analysis because they did not provide clear information on core requirements or because they followed an open-core model, which allows the student to customize the core requirements in consultation with an adviser. The exclusion left 45 liberal arts colleges and 45 research universities in the data set. For each of the ten curriculum areas, all courses were reviewed from the menus of selection using a search for the terms “climate change,” “climate science,” or “global warming.” If the term appeared in the course description, course title, or both, then the course was designated a “climate change” course. The percentage of climate-change courses for each of the ten curriculum areas was then estimated.

The method provides a straightforward estimate of percentage of climate-change courses, and it is not biased by non-responses or by incomplete reporting that can occur in survey methods. However, the method has a limitation because some courses may cover climate change but do not flag it explicitly in the course title or catalog description. Such courses were not captured in the search. To address this issue, it would have been necessary to go down to the level of course syllabi; however, not all syllabi are available online for evaluation, and more resources would be needed than were available to gather the thousands of syllabi for general education courses in the 100 colleges and universities. With this limitation in mind, the approach taken here provides a good general indication of the percentage of courses in which climate change or global warming is highlighted or significant enough to be depicted in the catalog description.

For each curriculum area for each school, the probability that a student would take a climate-change course was calculated based on sampling without replacement because the student cannot take the same course twice. Then for each school, the probability that a student would take a climate-change course across the entire core curriculum was calculated (1 minus the probability of taking all non-climate-change courses for each curriculum area). This method gives an estimate of the probability of taking at least one course designated as covering climate change under an ideal curriculum in which all courses in the core area are offered when the student makes a selection. In practice, this condition is not achieved, so the estimate can only be considered an approximation. However, it has value for comparison across the schools and as an indicator of how broadly climate change education is available in the core curriculum.

3. Results

3.1. Probability of taking a climate-change course in the core

To answer research question 1, the mean percent of climate-change courses in each core curriculum area was calculated as the average proportion of climate-change courses for each core curriculum area across all 90 schools (See Table 1.). For each area of the core curriculum, the percentage of courses that highlights climate change or global warming in their course descriptions is less than 10%. The table also shows the mean number of required courses for each curriculum area across all schools, and it provides the estimate of the average probability across schools that a student will take at least one climate-change course in each curriculum area. The mean probability of taking at least one climate-change course through the entire core curriculum across all schools is 0.17.

The highest percentage of climate-change courses is in the natural science area (5.1%). This area also has the highest mean number of courses required (2.0) and the highest probability estimate (0.07). Therefore, students are most likely to be exposed to climate change through natural sciences and related courses (including mathematics). Because Earth and Environmental Science departments are in this category, these results are consistent with expectations. The next highest area after the natural sciences and quantitative areas is in the social sciences, which is also to be expected because of courses on climate change and society, politics, economics, and policy.

Table 2 presents a ranking of schools based on the estimated probability of taking at least one climate-change course through completion of the core curriculum requirements. For research

Table 1
Summary Descriptive statistics for all schools, core courses. CC=Climate change.

Area of Core	Mean Percent of CC Courses	Standard Deviation	Mean Number of Required Courses in Core Area	Standard Deviation	At least One CC Course
Natural Science	5.1%	7.4	2.0	1.8	0.07
Quantitative	1.6%	3.4	1.0	0.8	0.02
Social Science	1.5%	3.1	1.5	1.0	0.02
First Year Seminar	0.9%	1.9	0.6	0.6	0.01
Ethics/Philosophy	0.6%	2.0	0.6	1.0	0.01
Writing	0.5%	2.3	1.0	1.2	0.01
International	0.3%	0.8	0.5	0.7	0.00
Humanities	0.2%	0.6	1.6	1.1	0.00
Diversity	0.2%	0.6	0.5	0.7	0.00
US History	0.1%	0.3	0.5	0.8	0.00
Other	2.6%	11.1	1.0	0.8	0.03
Mean of means	1.2%		1.1		

Table 2
Ranking of schools by probability estimate of taking at least one climate-change course in the core curriculum.

School Type	Ranking (1 = high, U=University, UC=University of California, US=United States)
Research Universities	1 Columbia, 2 UCLA, 3 UC Santa Barbara, 4 Dartmouth, 5 Boston College, 6 University of Illinois, 7 NYU, 8 Cornell, 9 Stanford, 10 U Rochester, 11 Northeastern, 12 U Pennsylvania, 13 Washington U, 14 UC Irvine, 15 U Chicago, 16 U Southern California, 17 Yale, 18 Harvard, 19 Northwestern, 20 Duke, 21 Notre Dame, 22 Princeton, 23 Georgetown, 24 U North Carolina, 25 Johns Hopkins, 26 U Michigan, 27 Vanderbilt, 28 UC Davis, 29 Carnegie-Mellon, 30 Rice, 31 Lehigh, 32 Case Western, 33 Pennsylvania State, 34 William and Mary, 35 U Virginia, 36 MIT, 37 Brandeis, 38 Emory, 39 Boston U, 40 UC Berkeley, 41 U Wisconsin, 42 U Florida, 43 Tulane, 44 Wake Forest, 45 Rensselaer Polytechnic Institute
Liberal Arts Colleges	1 Colby, 2 Bates, 3 Macalester, 4 Wellesley, 5 Wesleyan, 6 Williams, 7 Bowdoin, 8 Union, 9 Colgate, 10 Carleton, 11 Bucknell, 12 Whitman, 13 Lafayette, 14 Dickinson, 15 Soka U of America, 16 Skidmore, 17 US Military Academy, 18 Colorado College, 19 Holy Cross, 20 Sewanee, 21 Middlebury, 22 Swarthmore, 23 Barnard, 24 Haverford, 25 Trinity, 26 Washington and lee, 27 Bard, 28 Scripps, 29 Hamilton, 30 Mount Holyoke, 31 Oberlin, 32 Connecticut, 33 Grinnell, 34 Gettysburg, 35 Pomona, 36 Occidental, 37 Davidson, 38 Bryn Mawr, 39 Franklin and Marshall, 40 Claremont McKenna, 41 Vassar, 42 US Naval Academy, 43 US Air Force Academy, 43 Centre College, 43 Harvey Mudd

universities, the maximum probability is 1 at Columbia University followed by 0.443 at UCLA, the minimum probability is 0.023 at Rensselaer Polytechnic Institute, and the average is 0.205. For liberal arts colleges, the maximum is 0.320 at Colby College followed by 0.306 at Bates College, the minimum is 0 (three schools), and the average is 0.128.

3.2. Differences across types of colleges

To answer the second research question, schools were divided into three groups: private research universities, public research universities, and liberal arts colleges (See Table 3 and definitions above). The probability of taking at least one climate-change course through completion of all core requirements for each school was used to create the mean probability for all schools in the three categories. The mean probability for all research universities (public and private) and for all schools (research universities and liberal arts colleges) was also calculated. Research universities have a higher score than liberal arts colleges ($p < 0.01$, *t*-test, two-tailed), as do private research universities in comparison with private liberal arts colleges ($p < 0.02$, *t*-test, two-tailed). The difference may be explained by the size of research universities, which may increase the availability of climate-change courses.

In order to explore further the difference between private and public research universities, institutions were coded by the political control of their respective state legislatures (See Table 4.). This question is consistent with the research described above on barriers to the institutionalization of environmental education and the importance of economic resources and administrative support. Given the high degree of political polarization in the U.S., it was possible that there would be differences between states with Democratic Party control and those without such control because overall there are sharp policy differences across states for other sustainability issues such as renewable energy policy. Using data for 2013 and only for legislatures (not governor's office), states were divided into those with complete control of the legislature by Democrats versus those with complete control by Republicans or split control (National Conference of State Legislatures, 2013). The results show that there is a significant difference between the probability of taking at least one climate-change related course at public research universities with Democrat-controlled state legislatures versus Republican- or split-controlled state legislatures ($p < 0.02$, *t*-test, two-tailed). However, the difference was not significant for private research universities, which are more insulated from the effects of state legislatures.

Table 3
Mean probability of taking at least one climate-change course.

Institution Type	Mean Probability
Research Private (N = 31)	0.21
Research Public (N = 14)	0.19
Research Total (N = 45)	0.21
Liberal Arts Total (N = 45)	0.13
All Institutions (N = 90)	0.17

There are several possible explanations. Direct political bias could include the lack of motivation to hire faculty and to invest resources in the environmental curriculum, especially climate change, in public universities in states where the legislature is either partially or completely controlled by Republicans. However, it could also result from the general pattern of lower funding of public universities in Republican-controlled states, which might affect capacity to make investments in new areas. For example, McLendon et al. (2009) show that changes favoring Republican legislative control are associated with lower funding of post-secondary education. On average, interdisciplinary ES programs rely on institutional funds for roughly 40% of their budgets (Vincent et al., 2014). However, environmental programs often do not hold high priority status when institutions are allocating funds, and this

Table 4
Comparisons across state government types.

	Probability of Taking at Least one Climate -Change Course	
Institution Type	Republican- and Split-controlled state legislature	Both houses controlled by Democrats
Research Public	0.11 (N = 7)	0.27 (N = 7)
Research Private	0.16 (N = 13)	0.25 (N = 18)

is true across institution types (Vincent et al., 2015). In combination, these factors suggest that although it is difficult for environmental programs to gain administrative support across institution types, the problem is likely to be exacerbated in public universities where government budgets are being cut and where the topic is not popular with the dominant legislative party.

These relationships were further analyzed in a multivariate analysis with the dependent variable modeled as the probability of taking at least one climate-change course in the core curriculum (See Table 5.). Three independent variables were used (private = 1 and public = 0, research university = 1 and liberal arts college = 0, and location in Democrat-controlled "Blue State" state = 1 and in Republican or split state = 0, as defined above). Because the variables "Private" and "Research" are moderately correlated (0.3), two models were run. Only the variables "Blue State" (Democrat-controlled state legislatures) and "Research" (research universities) were significantly associated with the dependent variable. Log transformations of the dependent variable brought the skewness and kurtosis into an acceptable range but did not alter the significance or direction of the relationships. The multivariate models should not be overemphasized because of the small size of the data set, but they are consistent with the bivariate analyses.

Although the causal shaping factors (e.g., school type and legislature type) identified in this second research question are of interest, they should not detract from the results of the first research question: the percentage of climate-change courses offered as part of general education requirements is very low across nearly all colleges and universities. Students who wish to avoid such courses—either because their portfolio of academic interests does not prioritize climate change education or because they have ideological hostility to the topic—can find it easy to do so in most schools, although it appears less easy to do so if they are in a research university and in state where the legislature is controlled by the Democratic Party.

3.3. Review of best practices

To answer the third research question, general education programs that offer best practices were selected from the data set for more detailed analysis. These schools provide models of how colleges and universities can use the core curriculum to ensure that students do not graduate from college ignorant of climate science and climate change.

Columbia University (ranked 1 among research universities in Table 2) requires a "Frontiers of Science" course as part of the general education curriculum. This course explores scientific topics spanning multiple disciplines in the physical, natural, and life sciences and their relation to current society. Global climate change is included in the course description, and the syllabus indicates that the "Frontiers of Science" course includes an Earth science module. Because all students at Columbia College (the undergraduate degree-granting unit) are required to complete the course, the probability of a student learning about climate change is approximately 100%. Thus, one pathway is to have a single required course that explicitly requires education about climate change.

Another pathway toward higher exposure to climate science and climate change in the core curriculum is through a high volume of options. This approach has the advantage of not triggering curriculum battles, but it has the disadvantage of making it possible for students to complete their college educations without taking a climate-change course. The University of California at Los Angeles (UCLA) and the University of California at Santa Barbara (UCSB), ranked second and third among research universities in Table 2, do not have a specific course requirement that covers climate change such as the Columbia example, and they also do not have an environmental menu requirement. However, over 10% of the available natural science courses cover climate change, and multiple courses from natural sciences departments are required for graduation. Furthermore, the schools have more than one department that hosts climate-related courses, for example, UCLA's departments of the Environment; Earth, Planetary, and Space Sciences; and Atmospheric and Oceanic Sciences. Colby College, ranked first among liberal arts colleges, similarly has over 15% of its natural science offerings covering climate change from multiple departments, including Environmental Studies. Bates College, ranked second among liberal arts colleges, requires two themed general education concentrations, roughly 10% of which have an environmental theme. These concentrations include climate-change courses housed in departments ranging from Environmental Studies and Geology to English. By offering climate-change courses in multiple departments, these schools increase the proportion of courses that cover climate change in the general education curriculum.

A third approach is to have an environmental menu requirement, in other words, an area of core courses specifically designated for ES courses. This requirement did not appear very often in the sample, but two liberal arts colleges had this requirement and also ranked in the top third of the liberal arts colleges. Dickinson College (ranked 14 among liberal arts colleges in Table 2) requires a sustainability course, and Bucknell University (ranked 11 among liberal arts colleges) requires an "environmental connections" course. However, a closer look found that this general environmental requirement does not necessarily include climate-change education. At Dickinson College, only 5% of the courses in the sustainability menu explicitly include climate change, climate science, or global warming in the course descriptions. Although one would expect that some of the courses under the sustainability menu would cover climate change even if the topic is not flagged explicitly in the course description, it is also the case that the sustainability menu covers a variety of courses that may not do so, such as courses on international healthcare and business. Likewise, at Bucknell only 8% of the courses in the "environmental connections" menu explicitly mention climate change, climate science, or global warming in the catalog description, and courses on international modernization and astronomy fulfill the "environmental

Table 5
Association with probability of taking at least one climate-change course in the core curriculum.

	Model 1	Model 2
	b (se)	*b* (se)
Private	-0.016 (0.04)	0.019 (0.04)
Blue State	0.081 (0.03)**	0.082 (0.03)**
Research		0.085 (0.03)**
Intercept	0.13 (0.03)***	0.062 (0.04)
Adjusted R^2	0.07	0.15
F	4.1*	6.1***

*p < 0.05, **p < 0.01, ***p < 0.001, two-tailed.

connections" requirement. Because the sustainability requirements are broadly defined, students can meet graduation requirements without being exposed to climate science.

In summary, this analysis points to three pathways toward greater inclusion of climate science in the core curriculum: a specified core course that all students take and that has a climate-science component in it, offering a higher volume of climate-science and climate change courses within existing menus of core categories, and a menu requirement in the core curriculum for an environmental or sustainability studies course.

4. Discussion

Although climate change is arguably the most important global problem of the twenty-first century, this research project indicates that universities and colleges have failed to update the general education curriculum and ensure that all students are exposed to education about climate science and climate change. These findings are consistent with literature evaluating integration of ES concepts in higher education more broadly (Ceulemans et al., 2011; Wolfe, 2001; McIntosh et al., 2008). In most cases, the failure is probably not due to climate science denialism among faculty or due to their lack of concern with climate change; rather, the slow pace of change reflects the fact that professors and administrators tend to have other priorities for core curriculum reform. In this sense, American colleges and universities, and potentially colleges and universities in other countries as well, are "living in denial" (Norgaard, 2011): they recognize the importance of the problem but have not translated the awareness into action, in this case curriculum changes. The result is a situation of "curricular denialism" that has failed to educate students, especially those who are inclined to exercise confirmation bias by avoiding climate-science courses that might challenge denialist views that they have developed prior to attending college. This may explain the phenomenon of educational attainment having little effect on conservative and Republican individuals' belief in climate change (McCright and Dunlap, 2011).

Although the focus of this study has been on climate change and the core curriculum, there are other possible pathways toward embedding awareness of climate change and climate science in the college education. A vigorous series of lectures and campus events can help to instill a general awareness of and appreciation of the issue (Lozano et al., 2013). Another avenue might be to include climate education as part of first-year orientation requirements, although an attempt by the authors to do so in their university did not meet with much success because of the many demands placed on orientation training and events. A third approach is to shift individual courses to include one or two weeks on climate science and climate change education. Hess has done this with all courses that he teaches. Even if only a week or two is included in a course, students can gain important knowledge about climate science and climate change. Furthermore, by developing an informal list of starred courses, it is possible to encourage professors to add a module to their existing courses, and eventually such a list could become the basis for a core curriculum area requirement.

5. Conclusion

The analysis of the core curriculum of the leading colleges and universities in the United States is consistent with the general literature on the difficulties of institutionalizing ES education in the higher education curriculum. The result is that it is easy for a student to graduate with a bachelor's degree without being exposed to climate science or related climate-change topics through core curriculum requirements. The study also identified three best practices for improving the situation through core curriculum reform: a single core course required of all students, an increased volume of climate-related courses as part of the existing core-course options, and a menu of courses that would include climate-science or climate-change education. Additional approaches that do not require changes in the core curriculum were also discussed.

The results also suggest some structural conditions that affect the odds that a college or university will offer more courses related to climate science and climate change in the college core. First, because these courses appear with a greater frequency in the natural and social sciences, a core curriculum that is weighted toward these areas will tend to have more climate-related courses. Second, research universities, which are generally larger and have more courses, have a higher likelihood of offering a climate-related course as part of the core curriculum in comparison with liberal arts colleges. Third, in public universities in states where the legislature is completely controlled by the Democratic Party, the odds of offering more climate-related courses is higher than in states with legislative control by the Republican Party or with split party control. This finding is consistent with the high level of climate-science denialism in the Republican Party, but it could also be related to different levels of funding (both for education in general and funding for climate-related research).

This study has several general implications. It suggests the need for the analysis of ES studies in higher education to devote attention to the specific problem of climate-change education, a problem that is especially important in countries where there is widespread confusion about climate change or even climate-science denialism in the media and among some political leaders. It also suggests various pathways for improving the opportunity for college students to gain fundamental knowledge about climate science and climate change. Finally, the study suggests that research on variations in the availability of climate-science education may need to take into account the political priorities set by governments that monitor and affect higher education.

In summary, although climate change is arguably the most important global problem of the twenty-first century, universities and colleges in the U.S., and perhaps in other countries, have failed to update the general education curriculum to include education about climate change. More attention needs to be paid to this crucial topic, not only among ES researchers but also among faculty and administrators who have the power to alter the core curriculum.

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